IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of: **KHADAVI**	Examiner: A. Wahba
Serial No. **09/684,536**	
Filing Date: **October 6, 2000**	
Confirmation No. **1536**	Art Unit: 2661
For: **SYSTEM AND METHOD FOR BROADBAND ANALYSIS OF TELEPHONE LOCAL LOOP**	

DECLARATION UNDER 37 CFR §1.131

Mail Stop Amendment
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, **KAMRAN R. KHADAVI**, do hereby declare and state:

1. I am the sole inventor of claims 1-43 as originally filed in the above-identified patent application.

2. Prior to September 3, 1999, the effective date of U.S. Patent No. 6,266,395 to Liu et al., while employed at Harris Corporation in Camarillo, California, I conceived the invention of a bandwidth analysis tool that is operative as a system and method for broadband analysis of a telephone local loop. I worked diligently from conception in developing the software and hardware on which it is to be run, including pseudo-code, up to the time of filing the instant patent

application. My invention includes a system and method for analyzing a telephone local loop. In one aspect of the invention, the system and method determines the physical loop faults within the local loop, qualifies the local loop for a particular digital subscriber line (DSL) technology, quantifies the local loop by calculating the signal-to-noise ratio, and calculates the data rates of the local loop for a particular DSL technology.

3. The DSL technology could be symmetric or asymmetric DSL and the system could model the local loop by modeling resistance, inductance, capacitance, and conductance (RLCG) primary constants and the line parameters for various segments of the local loop. These line parameters can be modeled as based on frequency and RLCG primary constants. Also, a particular DSL technology could be selected from a configurable list of DSL technologies.

4. This conception is reflected in Exhibit 1, which is taken from my laboratory notebook. These entries reflect that I had defined basic measurements of the bandwidth analysis tool of the present invention on pages 98 and 99. Pages 101 and 102 define Shannon's law in terms of items that are known or measured relative to the present invention and

provides a list of measurements that may be obtained with the bandwidth analysis tool of the present invention.

5. Page 102 is a memorandum setting forth details regarding the requirements of the present invention showing the bandwidth analysis tool module requirements for relevant data. That memorandum sets forth details regarding what can be used to analyze a line for DSL capability and a failure threshold with individual paths/margin/fail indications.

6. Exhibit 2 is a brief memorandum detailing the intended physical platform for the bandwidth analysis tool of the present invention and the types of product output, measurement input, and requirements of a cable fill tolerance prediction tool. I note that the software would later be implemented for the model.

7. Exhibits 1 and 2 are dated before September 3, 1999, and show a basic conception of the system and method of the present invention for determining physical loop fault, qualifying and quantifying the local loop, calculating the data rates, and modeling of the local loop.

8. After September 3, 1999, I worked diligently on my bandwidth analysis tool with line modeling as shown in Exhibit 3, taken from pages 119-123 of my laboratory notebook. I also prepared preliminary pseudo-code as reflected in

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_______________________________/

Exhibit 4 and later drafted an invention disclosure. Exhibits 3, 4, and 5 reflect work accomplished after September 3, 1999. I worked diligently with the patent attorney to draft and complete a patent application covering my invention. This patent application was filed on October 6, 2000.

9. The dates are deleted on the sheets for Exhibits 1-5, with Exhibits 1 and 2 reflecting conception and work on my invention prior to September 3, 1999.

10. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

June 12, 2004
Date

Kamran R. Khadavi
KAMRAN R. KHADAVI

IEEE Std 743-1995 (Revision of IEEE Std 743-1984)

10. Test equipment measurement interfaces

page 91 Return Loss(f) = $20 \log_{10} \left| \frac{Z_{ref} + Z(f)}{Z_{ref} - Z(f)} \right|$ dB

100, 135, 600 or 900 Ω (Nominal impedance (Ω))

Full operating range of the set

page 92 Return Loss ≥ 15

page 92 Bridging loss(f) = $20 \log_{10} \left| 1 + \frac{Z_{ckt}}{2Z(f)} \right|$ dB

Z_{ckt} is nominal circuit impedance.

Bridging loss shall not exceed 0.2 dB (over operating freq range)

ADSL Band

Return Loss

page 69 ANSI T1.413 At U-C and U-R reference points the nominal impedance in the ADSL band shall be 100 ohms

The return loss relative to 100 ohms in the frequency range from 30 - 1100 kHz shall be ≥ 10 dB

page 70 ANSI T1.413-1995 (Page 166 ANSI T1.413-1998 issue 2) Longitudinal balance at U-C and U-R interfaces shall be > 40 dB over the frequency range 20 kHz to 1100 kHz with PSTN and POTS interfaces terminated with ZTC and ZTR respectively.

$$LBal = 20 \log \left| \frac{e_l}{e_m} \right| \text{ dB}$$

where,

e_l = the applied longitudinal voltage

e_m = the resultant metallic voltage appearing across a terminating resistor.

Page 70 T1.413-1995

10.4 ADSL noise interference into the POTS circuit

10.4.1 Steady State Noise

The idle channel noise on the POTS circuit shall not exceed 18 dBrnC at either the POTS or the PSTN interfaces with the ADSL system installed whether operating or not operating.

Exhibit 1

The power at any single frequency less than 15 kHz as measured by test equipment with a bandwidth of 30 Hz shall not exceed the greater of 0 dBrn or 10 dB below the measured idle channel noise.

10.4.2 Impulse noise

During initialization and operation of the ADSL system, with no holding tone applied to the circuit under test, there shall be no more than fifteen counts in fifteen minutes at a threshold of 47 dBrnC0 at either the PSTN or the POTS interface.

page 71
ANSI T1.413

During initialization and operation of the ADSL system, with a -13 dBm0 holding tone at 1004 Hz applied to the circuit under test, there shall be no more than fifteen counts in fifteen minutes at a threshold of 65 dBrnC0 at either the PSTN or the POTS interface.

not defined this way in issue 2 ??

These impulse noise requirements shall be met with each of the test loops specified in 10.2.1 with the ADSL system forced to re-initialize once per minute during the test interval.

ANSI standard T1.413 issue two

Get a copy ✓

Wandel & Goltermann
Appl. note 52

Estimation of the cable length.

$$\text{Length} = (NVP * c) / 4 * f_{res})$$

$$\text{Length}/m = (NVP * 300) / (4 * f_{res}/MHz)$$

$$\text{Length}/m = 300 / (4 * f_{res}/MHz * SQRT(\varepsilon_r))$$

NVP = nominal velocity of propagation (0.5 to 0.9 c)

ε_r = dielectric constants of the cable insulation

Shannon's channel capacity formula

maximum theoritical bit rate that can be achieved.

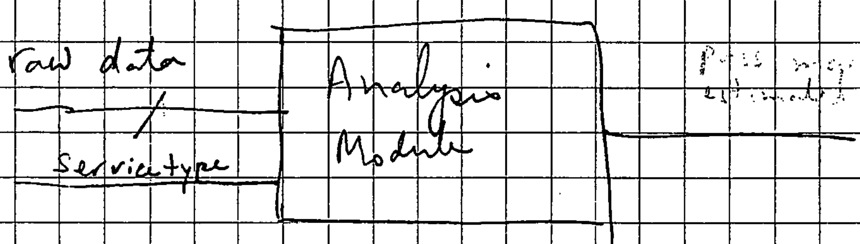
$$C = \int_W \log_2 (1 + SNR(f)) df$$

Where $SNR(f) = \frac{P(f)}{N(f)}$

$P(f)$ power spectral density (PSD) of transmitted signal in frequency band W

$N(f)$ the psd of broadband noise (such as white noise or crosstalk)

Bob — a) URL ~~ftp~~ — username and password for xDSL
b) Alcatel Modem test



raw data
1. Noise [dBrn, dBm or dBm/Hz]
2. Noise vs frequency [dBrn, dBm or dBm/Hz]
3. Impulse Noise
4. Bridged tap location and length
5. Loss [dBm] (loop loss measurement or input from customer)
6. Loop length [ft or meter]
7. RTU VER Code
8. Facility information

1. Deliverables (format, ..) — pseudo-code, equations, . . .
2. Schedule

4:00 PM

WTP Bandwidth Analysis Module Requirements

The current WTP design provides raw data results of various "wide band" copper cable anomalies. The purpose of the analysis module is to analyze these raw results both individually and collectively to determine the acceptance of the line to carry the desired xDSL service.

What Harris product actually performs the analysis is TBD, although it is likely CTS6000 in the near future. Eventually, WTP or its successor may perform this function as an optional module.

There are seven relevant data that can be used to analyze a line for DSL capability:

- Noise: A single result of noise averaged over a specified frequency range. Result is in dBrn, dBm, or dBm/HZ.
- Noise versus frequency: An array of measured noise averaged measured over a smaller frequency range (i.e. 4khz) duplicated up to 255 times over a wider frequency range. Results are in dBrn, dBm, or dBm/HZ.
- Impulse noise: A measure of number of counts of detected impulses over a specified threshold over a specified period of time. Result is in number of counts.
- Bridge tap location and length: Results are returned in length from RTU to "bridge" (connection of undesired pair), and the length of that "tap". Lengths are reported in feet or meters.
- Loss: The RTU may interact with a third party hand-held equipment located at the customer premises to perform wide band loss measurements. The user may also have the ability to manually input the loop loss into the system. Result is in dBm.
- Length: Loop length in feet or meters.
- RTU VER code: The majority of the time, the loop will not be wide-band tested if the RTU voice-band test failed, but some marginal loops may still allow xDSL service. Refer to the RTU manual for VER code information.
- Facility information: If a DLC is detected, that loop may or may not support all kinds of xDSL service. Digital Loop Carrier (pair gain junctions)

9. [illegible] 10 Load Coil Detection

Each of these will require a pass, marginal, and failure threshold that may or may not be different for each xDSL service available. In addition, the all of the noise measurements may have to be adjusted to estimate the worst case noise present (see attached document).

Now, the bigger problem. The results above may provide 8 individual pass/marginal/fail indications, but our customer wants to know only one result, "can this loop carry the desired xDSL service, and at what data rate?". A method must be developed to combine length with any number and any combination of the remaining 7 results to produce a pass, marginal, or failure result of the line under test and an estimated data rate. (Note: one possible solution is to try to normalize each of the results to a common unit {i.e. dBm} that can be added, and the total added error must be less than a defined mask". [illegible]

References: For ADSL-DMT, see T1.413, issue 2, For ISDN, T1.601; There are many references available on the T1.org web-site amongst others.

[illegible]

Actual Noise Amp [dBm] = measured Noise Amp + [Cable-loss/ft * Calculated Cable-length]

Bandwidth Analysis Tool Mini-MRD

Background

Digital Subscriber Line (DSL) provisioning and rollout is hampered by the transmission characteristics of the copper outside plant. One of the biggest challenges to a service provider is the estimation of the transmission technology type and potentially achievable bit rate of that technology on a specific telephone pair. The Bandwidth Analysis Tool is a software product that integrates RTU Multimeter testing, Wideband Test Pack (WTP) loop performance measurements, and cable records information to make a recommendation of the "best" service that a pair can provide.

Desired Product Output

1. The Bandwidth Analysis Tool output is a recommendation of the "best" technology and bit rate to use on a line. The meaning of "best" takes two forms. The first form is the fastest technology and the achievable bit rate of that technology. The second form is a more stable or reliable service technology that provides "good" data rates. Therefore, the output is two text items indicating the fastest technology and bit rate, and the more stable/reliable technology and bit rate.
2. The second use of the Bandwidth Analysis Tool is to start with a desired DSL technology and use the RTU test results to confirm that this technology will work on the selected copper pair.

Intended Platform

The Bandwidth Analysis Tool is intended to run on the CTS-6000 platform. Both the CUI and new GUI interfaces shall be supported.

Measurement Input

The following Remote Test Unit measurement data form the input to the Bandwidth Analysis Tool. (This list is important to achieve alignment between customer facing marketing collateral for the product and the actual technical solution behind the scenes.)

- RTU loop test results data including length.
- RTU loaded loop test.
- WTP noise margin spectrum data.
- WTP circuit loss data (two-ended loss test or some new single-ended technology)
- WTP wideband circuit balance.

- RTU loop resistance.
- WTP impulse noise reading??? (Takes too long; may not give real benefit).

Records or User Input

The following user input data is required to assist with the analysis.

- Cable pair gauge and makeup.
- Presence of Downstream DLCs.
- Presence of alarm circuits in the same binder group.

Phase 2 Feature: Cable Fill Tolerance Prediction Tool

Jonathan Chien raised the point that a service provider would want to be able to predict what would happen to existing DSL customers in a cable or binder group as new services were added. This would give them a tool to proactively perform bandwidth management and noise margin management of the outside plant without upsetting existing DLS services.

This feature is very powerful, but requires a full cable records dataload into the CTS-6000 database (or a way to externally access it) along with the storage of all of the new WTP data. The new product technology that would be required to support this feature are listed below:

- Full cable records with binder group data and DSL line identification.
- Storage of noise floor and circuit impedance data for each DSL line.
- Creation of a mathematical model to determine the incremental impairment of a DLS loop as a new disturber of a specific technology type is added to the binder group.
- Creation of software to implement this model over the large CTS-6000 data set and provide meaningful and usable output.
- This feature can be tied in with the Bandwidth Analysis Tool to warn the user of the potential upset of neighboring DSL lines and make a recommendation of a technology that causes the least spectrum impact to a cable binder group.

This is truly a Next Level Solution concept!

HDSL Line Code 2B1Q and CAP

Line Baud Rate

HDSL [TS 101 135 v1.5.1 (1998-11).pdf

The baud rate of the HDSL transceiver shall be:

- 392 kbaud ± 32 ppm for a three pair system
- 584 kbaud ± 32 ppm for a two pair system
- 1160 kbaud ± 32 ppm for a one pair system

Noise Margin

Gaussian noise

evaluating range between +27 dB and −5 dB

HDSL CAP

Line symbol rate shall be in the range of:

- 1168 kbit/s transceiver: 233,60 kbaud ± 10 ppm
- 2320 kbit/s transceiver: 386,667 kbaud ± 90 ppm

✓ AJJ- Sudhakar

Exhibit 3

ISDN, HDSL (DFE-based PAM signals)

$$\text{Margin} = \frac{1}{f_{band}} \int_0^{f_{band}} 10 * \log_{10}\left(1 + f\_SNR(f)\right) df - SNR\_req \quad dB$$

Where

$$f\_SNR(f) = \sum_{n=-2}^{1} \frac{S(f + f_{band} \times n)\,|H(f + f_{band} \times n)|^2}{N(f + f_{band} \times n)}$$

S(f) is the desired signal transmit power spectral density

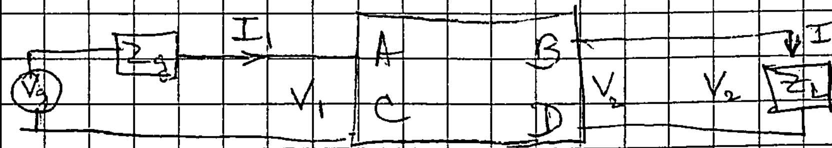
exponential probability distribution

$$\text{Prob}(\text{Number of DSLs in a binder} \leq n \mid SFH) = \int_0^{n+1} \frac{1}{\beta} e^{-x/\beta} dx$$

Use Microsoft Equation Editor

Transfer function of a Loop

$$T = \frac{V_2}{V_1} = \frac{Z_L}{AZ_L + B} \qquad 3.23 \quad [SA]$$



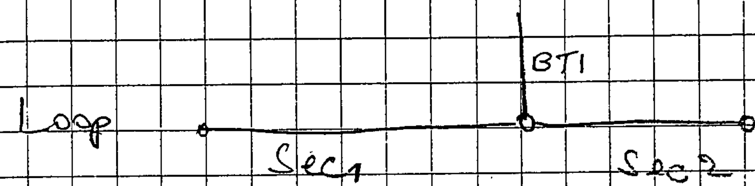
$$V_1 = AV_2 + BI_2 = AV_2 + B\frac{V_2}{Z_L}$$

$$\boxed{T = \frac{V_2}{V_1} = \frac{1}{A + \frac{B}{Z_L}} = \frac{Z_L}{AZ_L + B}}$$

Transfer Function of a Loop

ABCD of a bridged tap

$$ABCD_{tap} = \begin{bmatrix} 1 & 0 \\ \frac{1}{Z_{in_{tap}}} & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{1}{Z_{o,tap} \operatorname{Coth}(\gamma l_{tap})} & 1 \end{bmatrix}$$



$$\boxed{[ABCD_{tot}] = [ABCD_{Sec1}][ABCD_{BT1}][ABCD_{Sec2}]} \quad (1)$$

$$[ABCD_{Sec1}] = \begin{bmatrix} \cosh(\gamma L) & Z_o \sinh(\gamma L) \\ \frac{\sinh(\gamma L)}{Z_o} & \cosh(\gamma L) \end{bmatrix} \quad (2)$$

$[ABCD_{Sec2}]$ = similar to (2)

[http://www.labs.bt.com/profsoc/access/capacity.pdf
VDSL Capacity and Duplexing Scheme]

99/504 ADSL Margin Compilation

99/494R1 " " =

$$K = 8 \times 10^{-20} \times (n/49)^{0.6}$$

$$7.744 \times 10^{-21} = 8 \times 10^{-20} (n/49)^{0.6}$$

$$(n/49)^{0.6} = \frac{7.744 \times 10^{-21}}{8 \times 10^{-20}} = 0.0968$$

$$\left(\frac{n}{49}\right)^{0.6} = 0.0968$$

$$0.6 \log\left(\frac{n}{49}\right) = -1.0141$$

$$\log \frac{n}{49} = -1.69$$

$$\frac{n}{49} = 0.0204$$

$$n = 1$$

$$C(f) = \log_2\left(1 + \frac{S(f)\,|H(f)|^2}{N(f)\,\Gamma}\right)$$

$$\boxed{C(f) = \log_2\left(1 + \left(snr - snr\_margin - snrGAP\right)/10\right)}$$

4425_A TIA/EIA-568-B1
Commercial Building Telecommunications
Cabling Standard

4426 TIA/EIA-568-B.2

100 Ohm Balanced Twisted Pair
Cabling standard

Scaling SDSL test loops for different bit rates
ref ETSI 993t10a2

$Y = m \log(\text{bitrate}) + Y_0$

WIRE 26 Gauge

$$\begin{cases} 2400 = m \log(2048) + Y_0 \\ 4500 = m \log(384) + Y_0 \end{cases}$$

$m = -2872.78$

$Y_0 = 11911.76$

$\text{bitrate} = 10^{\frac{Y - Y_0}{m}}$ [kbps]

$\text{bitrate} = 10^{\frac{Y - 11912}{-2873}}$ [kbps]

$Y = 4500\text{m}$ $\text{bitrate} = 10^{\frac{4500 - 11911}{-2873}} \approx 380$ kbps

$Y = 2400$ $\text{bitrate} = 10^{\frac{2400 - 11911}{-2873}} \approx 2044$ kbps

Bandwidth Analysis Tool (BAT)
Engine Design Document
(Preliminary Pseudo-code)

Prepared by: **Kamran Khadavi**

Creation Date: **2000**

Revision: **1.4**

Revision Date: **2000**

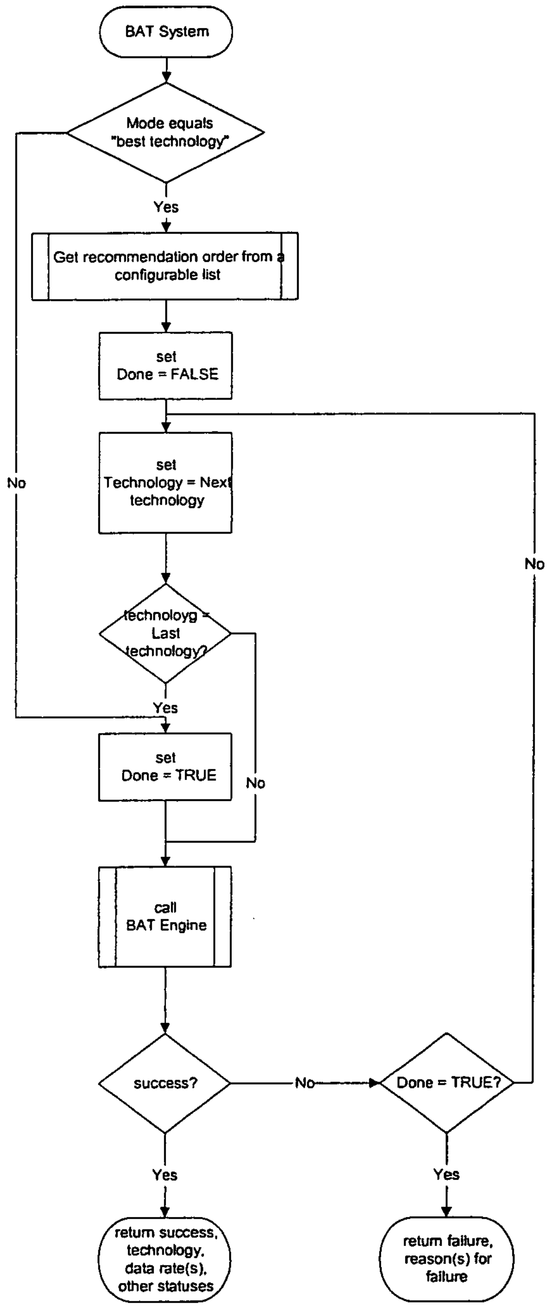
Revision History

Rev	Date	By	Description
1.0		Kamran Khadavi	Initial Draft
1.1		Kamran Khadavi	Added Model Loop and its functions
1.2		Kamran Khadavi	Added Calculate Insertion Loss function and more details to Calculate ABCD matrices function
1.3		Kamran Khadavi	Added Signal to Noise Ratio and Calculate Data Rate functions
1.4		Kamran Khadavi	Added BAT System and BAT Engine simplified flowcharts

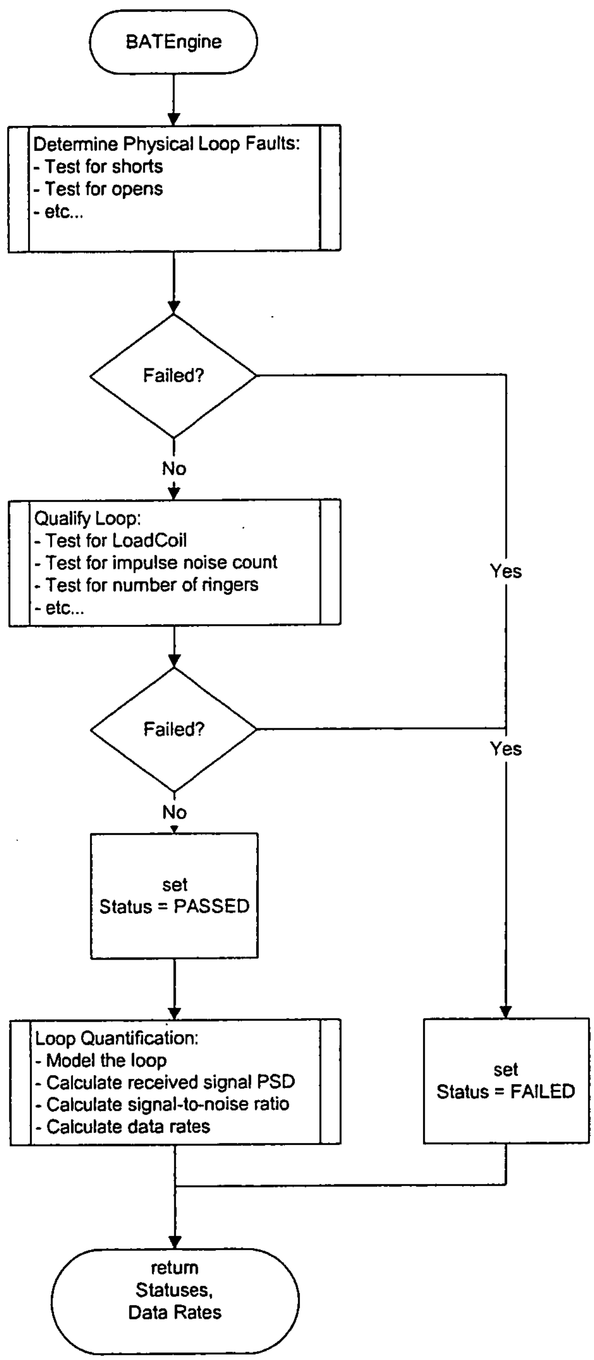
Exhibit 4

1. Overview

1.2 BAT System Simplified Flowchart



1.3 BAT Engine Simplified Flowchart



2. Pseudo-code BAT Engine

```
Inputs:
    Test Results from WTP, RTU and Plant data
    Threshold Data (technology and sub_tech dependent), from a setup
table
     Downstream and Upstream transmit Signal Data (technology
dependent),
    Technology ID

Outputs:
    Pass/Fail status
    Reason for failure and/or status information
    Downstream data rate
    Upstream data rate

{
        Determine Physical Loop Faults
        Analyze loop for xDSL
}    // end of BAT Engine pseudo-code
```

3. Pseudo-code to Determine Physical Loop Faults

```
Inputs:
    Test Results from WTP, RTU and Plant data
     Technology dependent Threshold Data (technology dependent)
     Technology ID

Outputs:
    Pass/Fail status
    Reason of failure

{
    if Load Coil Information is Available
    {
            if Load Coil Present
            {
                set PassFail = FAIL;
                set status Load Coil Present;
            }
            else
            {
            set PassFail = PASS;
            }
    }
    else
    {
            set Reason for failure, Load Coil Information Not
Available;
    }

}
```

4. Pseudo-code to Analyze XDSL

```
Inputs:
     Test Results from WTP, RTU and Plant data,
     Threshold Data (technology dependent),
     Downstream and Upstream transmit Signal Data (technology
dependent),
    Technology ID

Outputs:
     Pass/Fail status
     Reason of failure
     Downstream data rate
     Upstream data rate

{
   switch (Technology ID)
   {
         // symmetric technoloigies
         case BAT_HDSL:
         case BAT_HDSL_1160:
         case BAT_HDSL_584:
         case BAT_HDSL_392:

         case BAT_SDSL:
         case BAT_SDSL_144:
         case BAT_SDSL_400:
         case BAT_SDSL_784:
         case BAT_SDSL_1040:
         case BAT_IDSL:
              Analyze Symmetric DSL;
         break;

      // Asymmetric technologies
      case BAT_ADSL:
      case BAT_RADSL:
      case BAT_HDSL2:
         Analyze Asymmetric DSL;

      // VDSL is processed separately
      case BAT_VDSL:
         AnalyzeVDSL;
         break;

      default:
         set PassFail = FAIL
     set Reason for failure, technology not supported

    } // end switch (Technology ID)

 }   // end Analyze XDSL
```

5. Pseudo-code to Analyze Symmetric DSL

```
Inputs:
    Test Results from WTP, RTU and Plant data
    Threshold Data (technology dependent)
    Downstream and upstream transmit Signal Data (technology dependent)
    Technology ID

Outputs:
    Pass/Fail status
    Reason of failure
    Downstream data rate
    Upstream data rate
{
    Qualify Loop
    if Loop Qualified
    {

        switch (Technology ID)
        {
                case BAT_HDSL:
                case BAT_HDSL_1160:
                case BAT_HDSL_584:
                case BAT_HDSL_392:
                    Quantify HDSL
                break;

            case SDSL:
                case SDSL_144:
                case SDSL_400:
                case SDSL_784:
                case SDSL_1040:
                case SDSL_1568:
                    QuantifySDSL
                break;

                case BAT_IDSL:
                    Quantify IDSL
                break;


        } // end switch (Technology ID)

 }  // end Analyze Symmetric DSL
```

6. Pseudo-code to Analyze Asymmetric DSL

```
Inputs:
    Test Results from WTP, RTU and Plant data,
    Threshold Data (technology dependent),
    Signal Data (technology dependent),
    Technology ID

Outputs:
    Pass/Fail status
    Reason for failure
    Downstream data rate
    Upstream data rate

{
    Qualify Loop
    Quantify Loop

} // end Analyze Asymmetric DSL
```

7. Pseudo-code to Qualify Loop

```
Inputs:
    Test Results from WTP, RTU and Plant data,
    Threshold data (technology dependent),
     Technology ID

Outputs:
    Pass/Fail status
    Reason of failure

{
    if Load coil information available
    {
              if Load coil present
              {
                   set Pass/Fail status = FAIL;
                   Set Reason of failure status, Load Coil Present  =
TRUE;
              }
              else
              {
              LcoilPresent Status = FALSE;
              }
    }
    else
    {
              set status Load Coil Information Not Available =
NOT_AVAIALBALE;
    }

    if Impulse Noise test results available
    {
              if Impulse Noise Count less than threshold count
              {
                   set status ImpulseCountHigh = PASS
              }
              else
              {
                   set status PassFail = FAIL
                   set status ImpulseCountHigh = FAIL
              }
    }
    else
    {
              set status WimpulseTestNotAvailable = NOT_AVAILABLE
    }

    if  Number of Ringers less than threshold
              set Reason of failure status RingerFault = PASS
    else
    {
              set status PassFail = FAIL
              set Reason of failure status RingerFault = FAIL
    }

 } //  end Qualify Loop
```

8. Pseudo-code to Quantify Loop

```
Inputs:
    Test Results from WTP, RTU and Plant data,
     Threshold data (technology dependent),
     Signal Data (technology dependent),
     Technology ID

Outputs:
    Pass/Fail status
    Reason of failure
    Downstream data rate
    Upstream data rate

{
    Model Loop   (note: currently identical for both directions)
    setup power spectral density of transmit data for downstream
tranfers
    setup downstream signal-to-noise-ratio array
    calculate downstream data rate

    setup power spectral density of transmit data for upstream tranfers
    setup upstream signal-to-noise-ratio array
    calculate upstream data rate

} //  end Quantify Loop
```

9. Psuedo-code to Model Loop

```
Inputs:
        Number of Channels,
        Start Frequency,
        Delta Frequency,
        Test Results,
        Technology ID,

Outputs:
        Loop Data


{
        set source and load impedances
        If Wire Gauge Information available
                Set Wire Gauge
        Else
                Set Wire Gauge to default wire gauge

        If Bridged Tap Information is not available
                Set number of taps to zero
        Else
        {
                Calculate Loop's ABCD matrices
        }

        Calculate Insertion Loss of the loop

} // end Model Loop
```

10.

11. Pseudo-code to Calculate Loop's ABCD Matrices

Inputs:

Number of Channels
Start Frequency
Delta Frequency
Length of the segment
Wire Gauge
Bridged Tap Flag
Loop Data

Output:

Loop Data

```
{

    initialize loop [ABCD] to unity
    do for all segments of the loop
    {

        Do for the frequency range
        {
            Model the RLCG Constants
            Model Line Paramters
            If it is Bridged Tap section
            {
                A = 1
                B = 0
                C = Ctanh (Gamma)
                D = Ctanh(Gamma)/Z0;
            }
            else
            {
                A = D = Ccosh (Gamma)
                B = Csinh(Gamma) * Z0;
                C = Csinh(Gamma) /Z0;
            }

            Multiply by the accumulated [ABCD] from previous segments
        } // end do for the frequency range
    } end do for all segments of the loop

} // end Calculate loop's ABCD matrices
```

12. Psudo-code to Model the Primary Constants RLCG

Inputs:

```
Frequency in kHz
Wire Gauge
```

Outputs:

```
Primary Constants, RLCG
```

```
{
        if Wire Gauge Information Available
                set cable model parameters based on the wire gauge
        else
                set cable model parameters using average of AWG_24 and AWG_26

        Calculate Primary Constants, RLCG

}
```

13. Pseudo-code to Calculate Insertion Loss

```
{
    Do for all channels
    {
        set load impedance (Z_load) for the current technology
        set source impedance (Z_source) for the current technology
        Insertion Loss = 20 * log (abs ((A * Z_load + B + Z_source *
                    (C * Z_load +D))/Z_source + Z_load)))
    } // end of for all channels}  // end of Calculate Insertion Loss
```

14. Pseudo-code to Calculate Line Paramters

Inputs:

Frequency
Primary Constants (RLCG)

Outputs:

Line Parameters

```
{
        Z = R + j*2*PI*f*L;
        Y = G + j 2PI*Frequency*C;
        Gamma = Csqrt(Z*Y);
        Z0 = CSqrt(Z/Y);
} // end Calculate Line Paramters
```

15.

16. Pseudo-code to Setup Signal to Noise Ratio

```
Inputs:
        Number of channels
        Start Frequency
        Delta Frequency
        PSD data
        Wmargin data
        Loop data
        Downstream flag

Outputs:
        Signal to noise ratio for all channels
{
Do for all channels
{
                convert transmit signal PSD from dBm/Hz to dB
                calculate signal level at receiver end
                convert noise to dB
                signal to noise [dB] = signal [dB] - noise [dB]

}       // end for all channels
}       // end Setup Signal to Noise Ratio
```

17.

18. Pseudo-code to Calculate Data Rate

Inputs:

    Bat Results
    Number of Channels
    Start Frequency
    Delta Frequency
    Signal to noise data
    Technology ID
    Downstream flag

Outputs:

    Downstream/upstream data rate

```
{
        Switch (Technology ID)
        {
                case BAT_ADSL:
                if (Downstream)
                {
                        for channels 33 through 255 (excluding channel 64)
                                signal_to_noise [dB] = signal_to_noise - snr_margin  - snr_gap
                                if (signal_to_nois > 0)
                                {
                                        Delta Capacity  = log2(1 + pow(10.0,0.1*signal_to_noise
        [dB]))
                                        If (Delta Capacity > MAX_BIT)
                                                Delta Capacity = MAX_BIT
                                        If (Delta Capacity < MIN_BIT)
                                                Delta Capacity = MIN_BIT

                                        Downstream Data Rate = Downstream Data Rate +
                                                        Delta Capapcity * data_frame_rate
                                }
                }
                else
                {
                        for channels 6 through 31 (excluding channel 16)
                                signal_to_noise [dB] = signal_to_noise - snr_margin  - snr_gap
                                if (signal_to_noise > 0)
                                {
                                        Delta Capacity  = log2(1 + pow(10.0,0.1*signal_to_noise
        [dB]))
                                        If (Delta Capacity > MAX_BIT)
                                                Delta Capacity = MAX_BIT
                                        If (Delta Capacity < MIN_BIT)
                                                Delta Capacity = MIN_BIT

                                        Upstream Data Rate = Upstream Data Rate +
                                                        Delta Capapcity * data_frame_rate
                                }
                }

                break;

                case HDSL2:
                Not implemented yet
```

```
                break;

                case BAT_VDSL:

                break;

                default:
                        for all channels
                        {
                                signal_to_noise ratio = signal_to_noise ratio - snr_margin - snr_gap
                                if (signal_to_noise_ratio > 0)
                                {
                                Delta Capacity = log2(1 + pow(10, 0.1 * signal_to_noise ratio))
                                Total Capacity = Total Capacity + Delta Capacity * data_frame_rate
                                }
                        }

        }

} // Calculate data rate
```

HARRIS CORPORATION

PROPRIETARY INFORMATION

INVENTION DISCLOSURE

(Accompanying Extension to Record of Invention)

Division:	NSD
Folder #:	DR-224

Invention Title:	**Bandwidth Analysis Tool (BAT)**

FIELD OF THE INVENTION

The present invention is directed to communication systems in general, and is particularly concerned with qualifying and quantifying loops for DSL (Digital Subscriber Line) technologies and/or recommending the best technology, for a given application, for the loop under test.

BACKGROUND OF THE INVENTION

The inability to pre-qualify copper loops accurately has been a significant obstacle for the local exchange carriers (LECS). Pre-qualification is critical because all flavors of Digital Subscriber Line (DSL) deployment is dependent on the design and quality of the outside plant (OSP) and DSL technologies are blocked by the presence of load coils. Pre-qualification is the testing of loops to determine if the loop is capable of supporting DSL transmission prior to attempting to provide service – a hot topic in the industry. The ability to qualify a loop without having to dispatch technicians to either the central office (CO) or the customer's premises will result in significant cost savings for the LEC. The significant number of DSL services projected by the industry implies a strong need for an automated testing capability to handle the growing line volume.

The loop qualification goal is to predict a loop's capability to support Digital Subscriber Line (DSL) services across the entire range of frequencies over which the technology operates.

The current Wideband Test Pack (WTP) design provides raw data results of various "wide band" copper cable anomalies. The purpose of the Bandwidth Analysis Tool (BAT) is to analyze these raw results both individually and collectively to determine the capability or acceptance level of the line to carry the desired DSL service.

SUMMARY OF THE INVENTION

The Bandwidth Analysis Tool (BAT) analyzes the raw data results from the Wideband Test Pack (WTP), and plant record data, to qualify and quantify the loop under test for a particular DSL technology. Alternatively, the Bandwidth Analysis Tool (BAT) analyzes the WTP data and plant record data to recommend the best technology for a given application. The analysis consists of loop qualification and quantification based on the WTP raw data results, plant record data, loop topology and insertion loss of the loop. The insertion loss of the loop is calculated by modeling the loop, with or without bridged taps, taking into account the cable type and gauge and loop length and topology. Signal to noise ratio of the received signal is calculated using the technology dependent transmit signal power spectral density templates and noise versus frequency data results from the Wideband Test Pack (WTP). The downstream and upstream data rates are calculated for the loop under test.

The algorithm for loop qualification and quantification consists of two principle functions:
1. Determination of physical loop faults
2. Analyzing for DSL technology

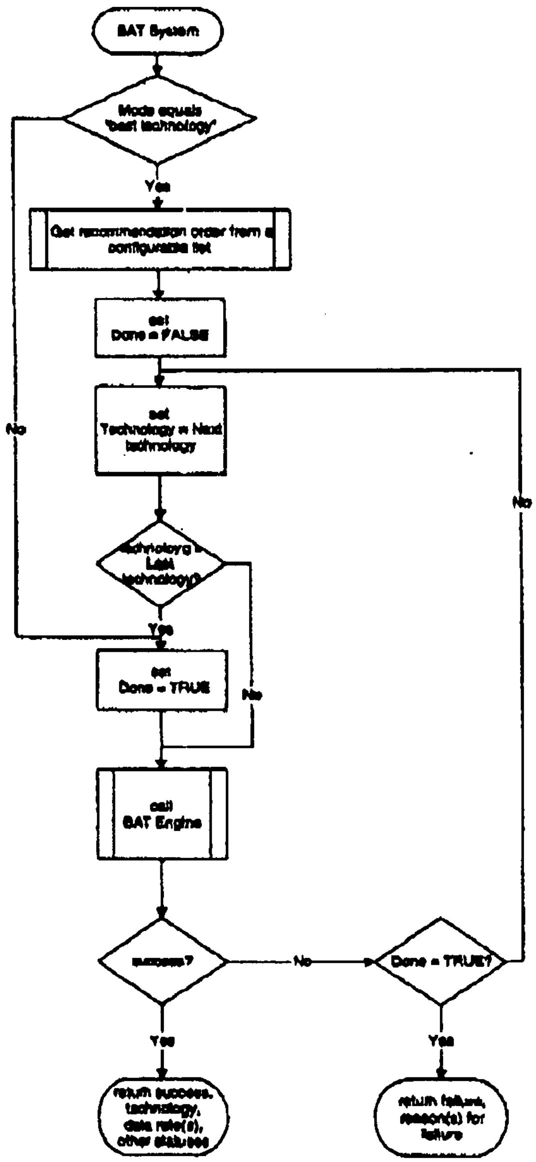
Determination of physical loop faults is performed by testing for shorts, opens, load coils, etc.
Analyzing for DSL technology is performed by analyzing for symmetric DSL or asymmetric DSL as appropriate. Loop qualification is done by testing for presence or absence of load coils, impulse noise counts, and ringers counts and comparing the counts with thresholds specified by the given technologies.

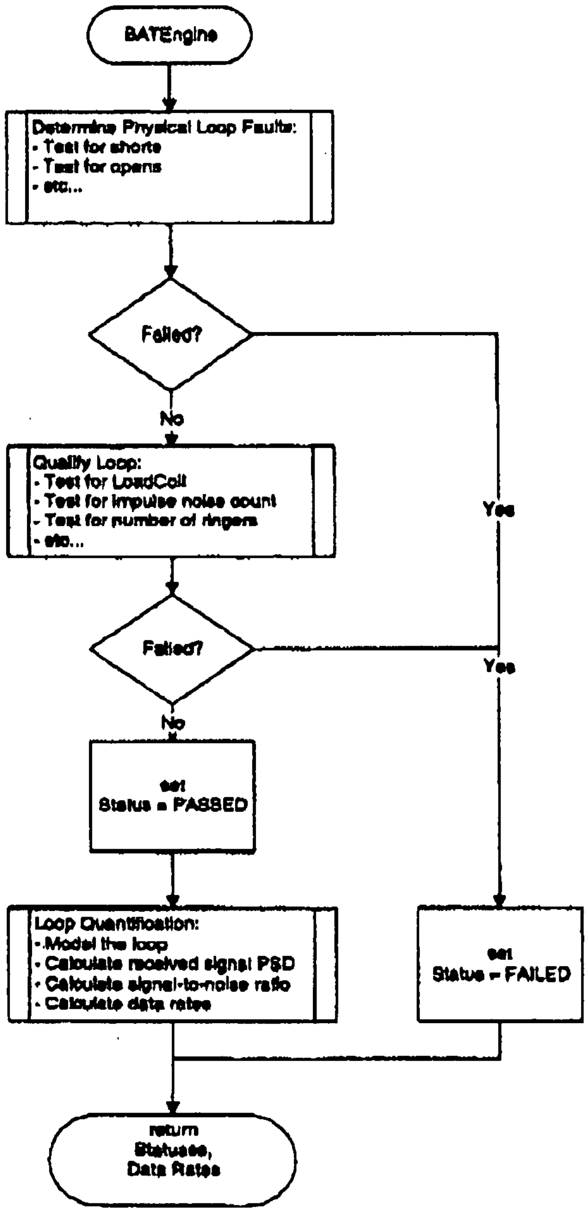
Loop quantification is performed for DSL technologies by modeling the loop under test, calculating signal to noise ratio and calculating data rates. In the case of symmetric DSL technologies, downstream and upstream data rates are equal. In the case of asymmetric DSL technologies, downstream and upstream data rates are calculated based on downstream and upstream transmit signal power spectral densities (PSD), insertion loss and noise versus frequency measurements.

Loop quantification for VDSL is performed as a special case, due to the restrictions of the bandwidth of WTP. In the case of VDSL, loop quantification is performed based on the loop topology rather than using signal to noise ratios.
In the case the mode is set to "recommend best technology", the technology is set to a DSL technology from a configurable list of technologies and the analysis is performed for each technology in the list until the loop qualifies or continues analysis of the loop for the next technology in the list or the list is exhausted, in which case the program returns "Failed" status. In the case the loop qualifies for a DSL technology, the status is set to "Pass" and the recommended technology is set to the current technology for which the loop is being analyzed for, and calculated data rate(s) are returned.

The following flowcharts depict a simplified high-level flow of the algorithms:

For further information, refer to Bandwidth Analysis Tool (BAT) pseudo-code.




BATEngine
Determine Physical Loop Faults:
- Test for shorts
- Test for opens
- etc...
Failed?
No
Yes
Qualify Loop:
- Test for LoadCoil
- Test for impulse noise count
- Test for number of ringers
- etc...
Failed?
No
Yes
set
Status = PASSED
Loop Quantification:
- Model the loop
- Calculate received signal PSD
- Calculate signal-to-noise ratio
- Calculate data rates
set
Status = FAILED
return
Statuses,
Data Rates

KNOWN PRIOR ART (IF ANY)

None known at this time.